BURNING WOOD WASTE FOR COMMERCIAL HEAT AND POWER

BY J. F. BARKLEY AND R. E. MORGAN

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ERRATUM

In table 2, items 31, 32, 33, and 34 should be in degrees Fahrenheit instead of degrees Centigrade.

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INTRODUCTION

Wood burned for commercial heat and power usually is waste material from some manufacturing process. The amount of it reaches substantial proportions. It is estimated that over 50 percent of the timber cut for lumber becomes "waste" in the process - sawdust, shavings, trimmings, slabs, and bark. Woodworking manufacturing processes also produce much waste. The incentive to use this waste has resulted in much development of wood-burning equipment to produce heat and power. To answer general inquiries received by the Bureau, this publication covering developments along these lines was written. There is included a bibliography of additional information on the subject.

COMPOSITION AND BURNING CHARACTERISTICS OF WOOD

The approximate composition of moisture-free wood is, in even figures:

	Percent
Hydrogen......	6
Carbon........	49
Oxygen........	44
Ash...........	1
Total.....	100

This composition corresponds to about $C_6H_{10}O_5$. Moisture is essentially always associated with wood. Green wood contains approximately 30 to 50 percent moisture; air-dried or seasoned wood contains 15 to 25 percent and kiln-dried about 8 percent. Exposed to the weather, wood absorbs and gives off moisture depending on weather conditions and water contact.

"Dry" wood ignites relatively quickly and readily gives off volatile matter when heated. Long flames and smoke easily occur during burning. The burning action is substantially retarded, however, by appreciable moisture content; ignition is more difficult. When the moisture content is more than about 70 percent, an auxiliary fuel is required to maintain combustion. One of the main factors in the problem of the satisfactory and smokeless combustion of wood is its moisture content.

TYPES OF WOOD-WASTE FUELS

Where only a small quantity of wood waste is produced at a plant, it is frequently burned in the form as produced, such as a mixture of trimmings, chunks, shavings, and sawdust.

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Where a large quantity is made up of pieces of various sizes, they are generally run through a "hogging" machine, after which shavings and sawdust may be added. A hogging machine chips the wood to a more uniform product called "hogged fuel" that can be handled and burned more efficiently. There are numerous types of hogging machines. Basically, they consist of sharp knives fastened to a rapidly rotating shaft or drum surrounded by a housing, a section of which is equipped with heavy plate, against which the wood is chipped. Figures 1 and 2 show two types of hogging machines. Hogged fuel is measured by volume, the standard unit being 200 cubic feet without packing; its weight varies widely, depending on the type of wood, the mixture of sizes, and the water content, say from 2,500 pound with the lower moistures of about 30 percent to 5,500 pound with the higher moistures of about 50 percent.

Sawdust with the chips removed is used as fuel, particularly for smaller commercial buildings. Sawdust with and without shavings and other small wood refuse also is briquetted. These briquettes usually take the form of pellets about 1 inch in diameter by 1 inch in length, suitable for stoker use, or of cylindrical briquettes about 4 inches in diameter and 12 inches in length, weighing about 8 pounds each, for hand firing. Sander dust is used for fuel at some mills. This is a fine wood dust produced in smoothing the surface of wood with sanding machines.

At some plants the wood waste burned is principally bark. This may vary in moisture content from 40 to even 80 percent. Tanbark or spent bark is the fibrous portion of ground oak or hemlock bark used in tanning leather. As fired, it is a pulpy mess containing 65 to 80 percent moisture.

HEATING VALUE AND ANALYSES

An average calorific value of moisture- and resin-free wood is about 8,300 B.t.u. per pound; that of resin is about 16,900 B.t.u. per pound. Among woods whose calorific value is considerably influenced by varying contents of resin are long-leaf pine, short-leaf pine, loblolly pine, western yellow pine, pinion pine, pitch pine, cedar, juniper, and cypress. The calorific value cannot be calculated closely from the analysis because of the high oxygen content and the effect of varying amounts of resins. Table 1 gives example analyses of wood fuels.

TRANSPORTATION TO PLANT

The method of transporting log wood to the mill may affect the exact analysis of the resultant wood waste. If logs are dragged overland, a considerable amount of sand and other earthen material may collect on the bark and surfaces of the wood. Such undesirable material increases the ash of the wood-waste fuel. As the amount of the natural ash of the wood is quite low, this increase may be relatively high. If the logs are floated, the moisture of the bark and surfaces may increase; if floated in salt water, salts and marine growths may accumulate on the surface. It is desirable to remove foreign ash material if possible. Figure 3 shows a water-spray method of reducing the amount of such material before the log enters the processing plant.

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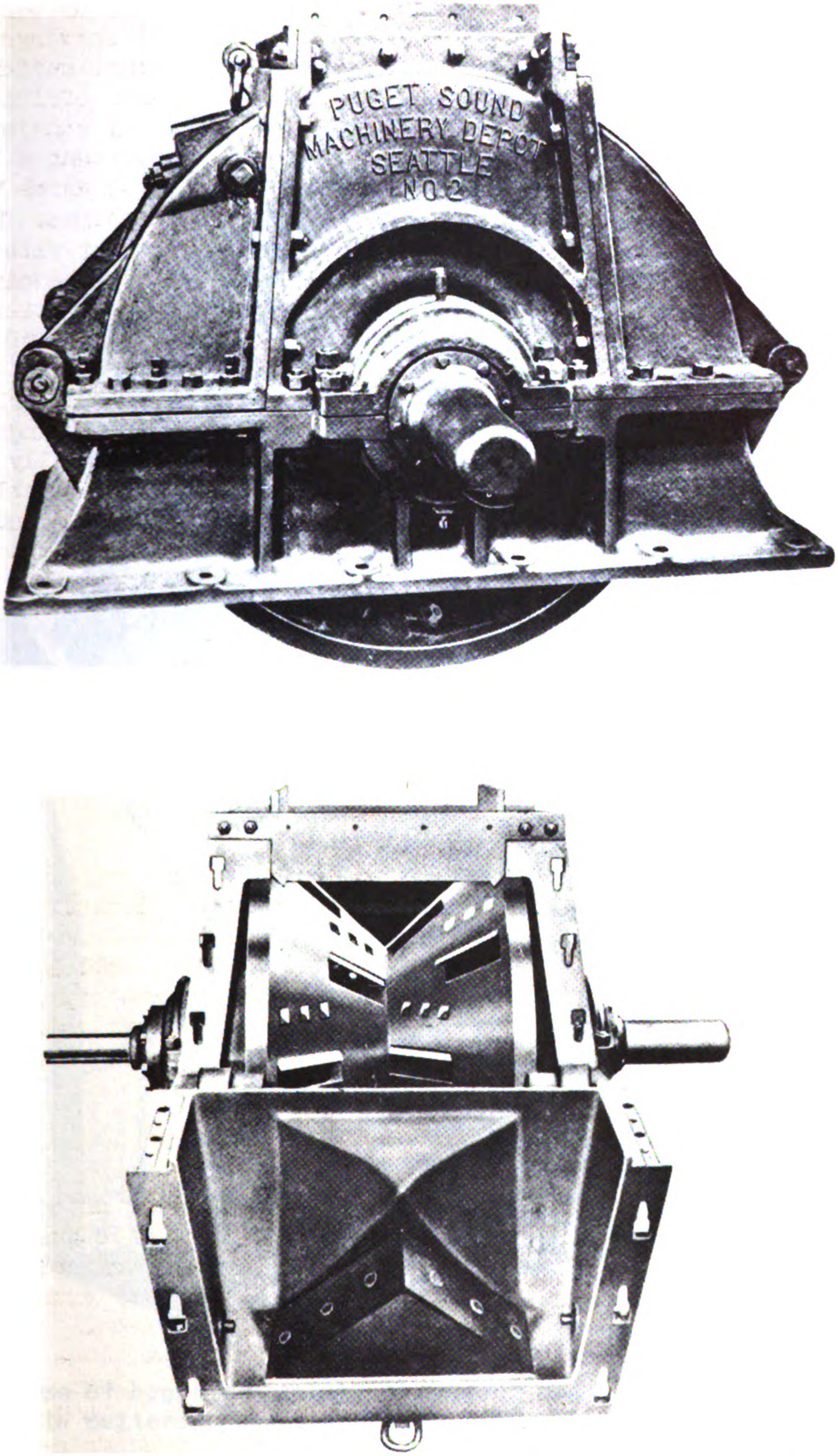

Figure 1. - Type of hogging machine. (Top) Side view. (Bottom) Casing opened showing revolving drum with cutters. (Courtesy, Garrett and Shafer Engineering Works, Seattle, Wash.)

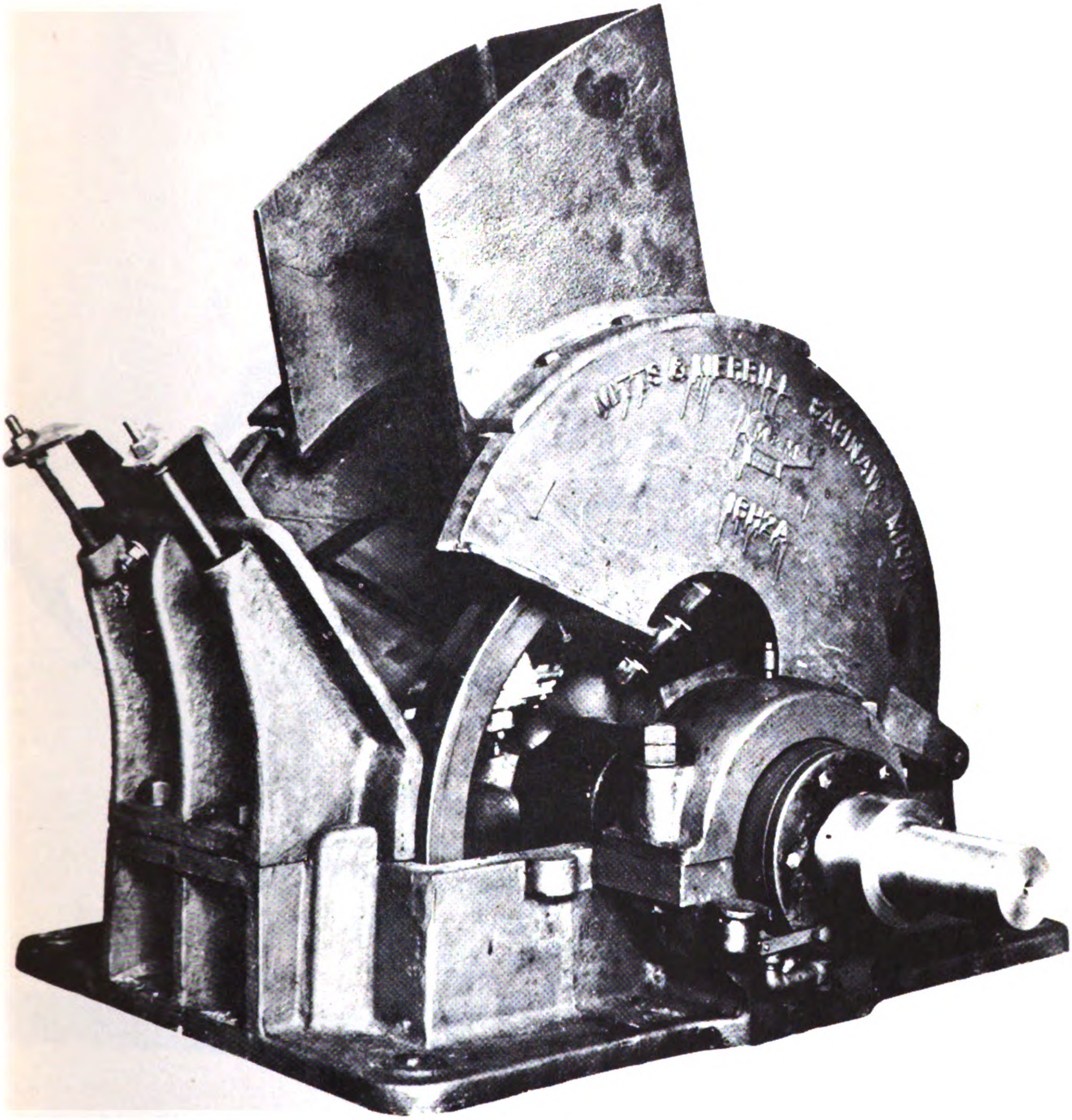

Figure 2. - Type of hogging machine, top casing open to show revolving drum with cutters. (Courtesy, Mitts & Merrill, Inc., Saginaw, Mich.)

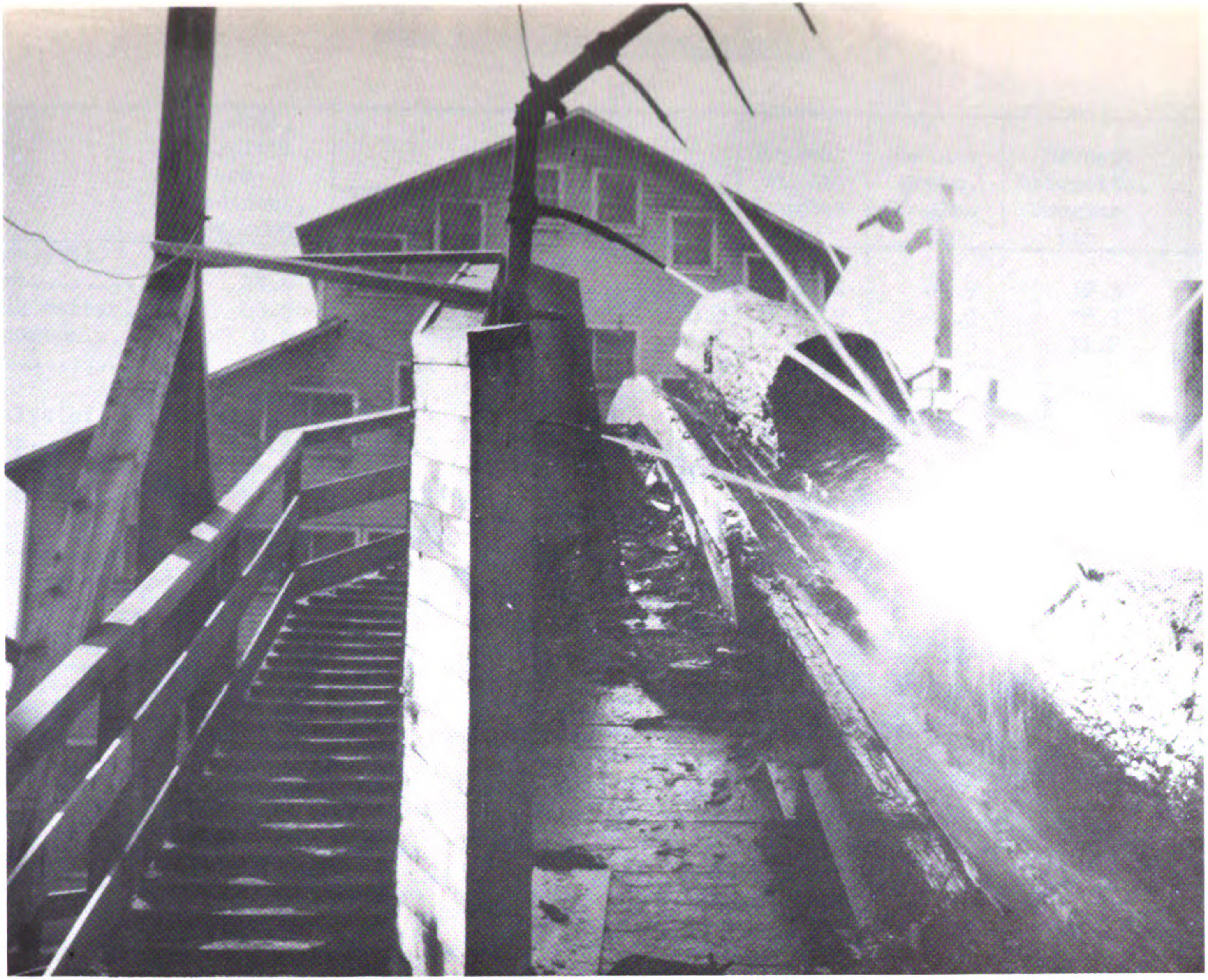

Figure 3. - Water-spray method of removing dirt and foreign material from the bark of logs previous to entering process plant.

TABLE 1. - Analyses of wood fuels

	Wood, typical non-resinous, seasoned.	Wood waste			Hogged fuels, Douglas fir	Sawdust green, Douglas fir	Sawdust briquetts, Douglas fir	Tan bark
		California redwood	Western hemlock	Douglas fir				
Proximate analysis:								
Moisture........	24.0	50.4	57.9	35.9	47.2	44.9	10.3	71.8
Volatile matter.	65.5	40.9	31.3	52.5	42.9	44.9	78.3	22.4
Fixed carbon....	9.5	8.6	9.9	11.1	8.9	9.5	11.2	4.5
Ash.............	1.0	.1	.9	.5	1.0	.7	.2	1.3
Ultimate analysis:								
Hydrogen........	7.2	8.5	8.9	8.0				9.6
Carbon..........	37.9	26.5	21.2	33.5				14.2
Nitrogen........	.1	.1	0	.1				0
Oxygen..........	53.8	64.8	69.0	57.9				74.9
Sulfur..........	0	0	0	0				0
Ash.............	1.0	.1	.9	.5				1.3
B.t.u. per pound.....	6,300	4,570	3,630	5,800	4,670	4,910	8,130	2,600

Owing to its low heating value per unit of volume as well as per pound, the cost of transportation of wood waste per 1,000,000 B.t.u. is relatively high. Usually, its use for fuel is economical only near lumber mills or where some low-cost means of transportation is available, such as by barges. Figure 4 shows a special type of clamshell for moving wood waste.

STORAGE

As the supply of wood-waste fuel, particulary for the larger users, is seldom continuously available, it is usually necessary to provide for some storage. When it is a byproduct of the manufacture of lumber, the quantity of wood waste produced depends on the lumber output of the mill, which varies with demand, and also on weather conditions in the logging area. Many mills smooth out their working schedule to some extent by storing logs on land or in water, but these storage facilities often are insufficient. Figure 5 shows logs in storage in mill pond.

When storing hogged fuel in the open, it is advisable to build the pile as high as possible rather than spread the fuel over a greater base area. This tends to lower absorption of moisture from rain and snow. Various types of bulk-handling storage equipment can be used. Figure 6 shows dragline methods to move the fuel, a large rake being used in one case and a drag bucket in the other. Figure 7 shows the use of a bulldozer for distribution.

Some changes occur in wood while in storage. W. E. Briggs, Superintendent of Steam Plants of the Portland General Electric Co., one of the largest storers and users of wood-waste fuel, reports by letter as follows:

> Our experience with fir hogged fuel stored in large piles for one year would indicate the following:
>
> 1. Loss in volume about 20%. This is due to settling and compacting of the fuel and does not represent any weight loss. This shrinkage in volume varies with the type of fuel, that is, the percentage of shavings, sawdust, and chips.
>
> 2. Volatile, moisture, and B.t.u. content are affected very little. Increase in moisture content will depend largely on weather conditions while pile is being built. Total loss in B.t.u. content is probably never over 5%.
>
> 3. The big change that takes place is in "burnability." The fuel in storage loses its fiber strength and tends to lay on the furnace grates in a compact mass, making it difficult to introduce combustion air properly. This characteristic of fuel reclaimed from storage appreciably affects both furnace efficiency (because of greater excess air) and furnace capacity (smaller amount of fuel can be burned per hour).

It is good practice to use stored wood within 1 year. Longer periods may show greater losses, particularly in volatile-matter content.

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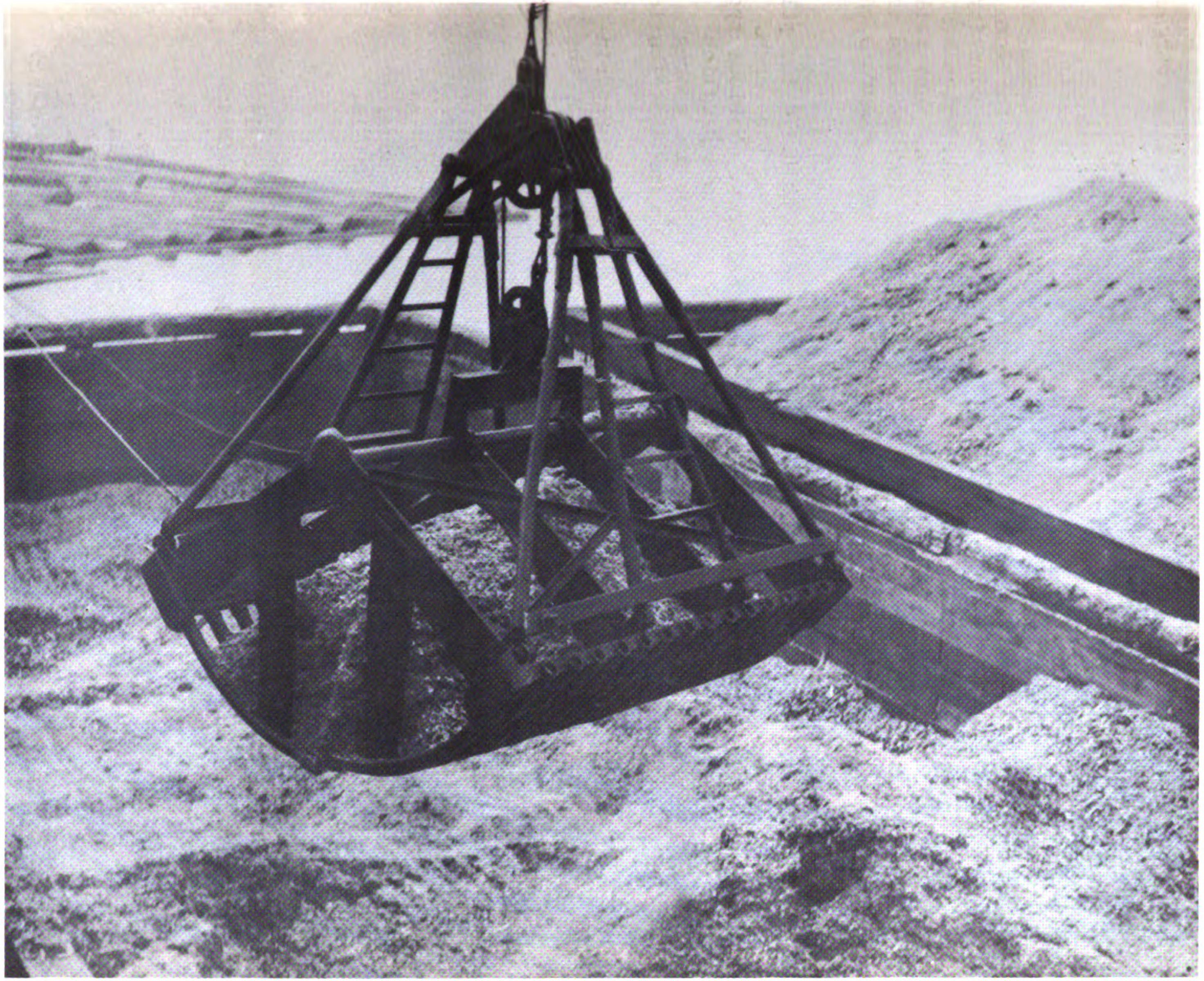

Figure 4. - Special type of clamshell for moving wood waste.

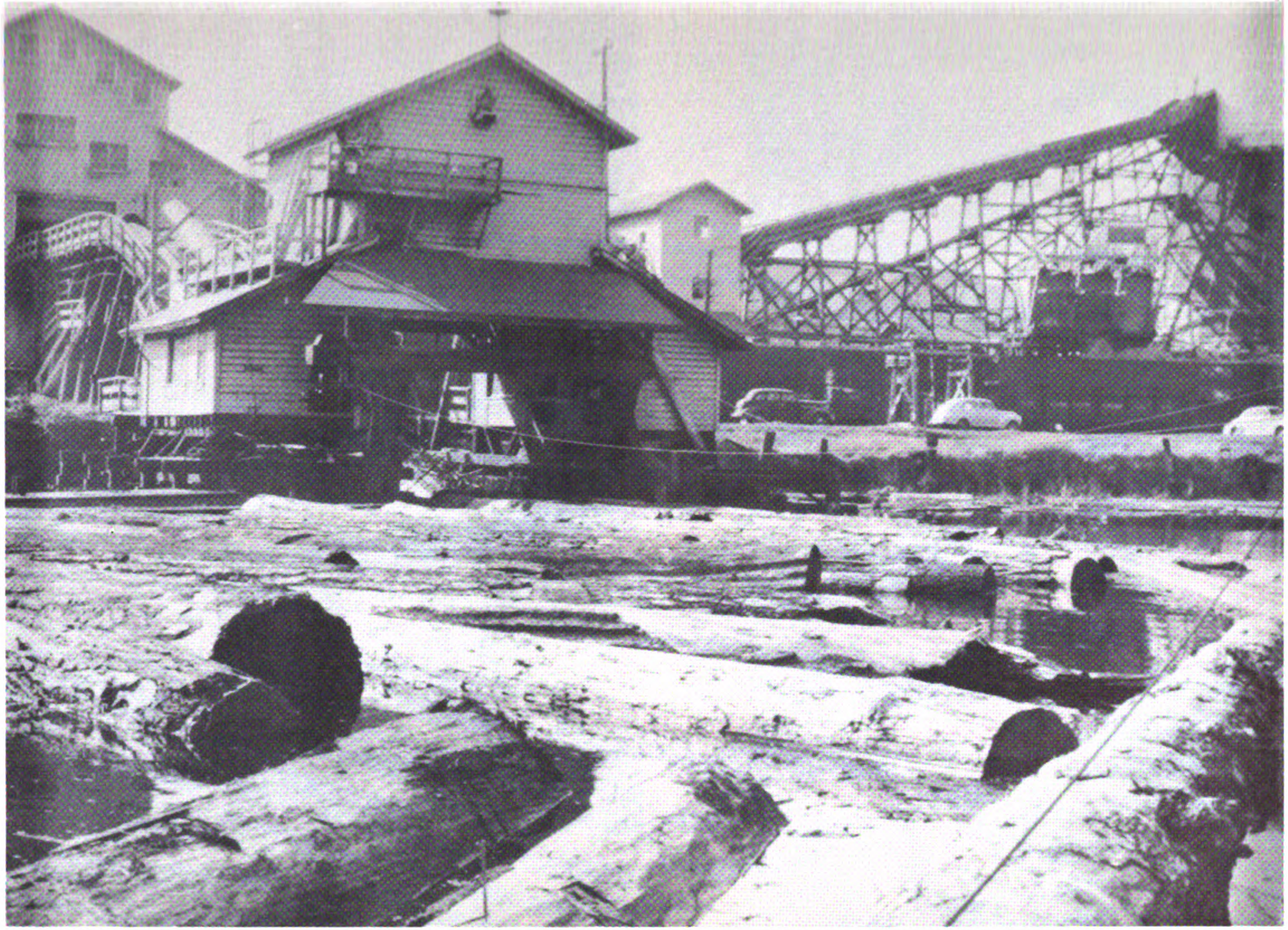

Figure 5. - Logs in storage in mill pond.

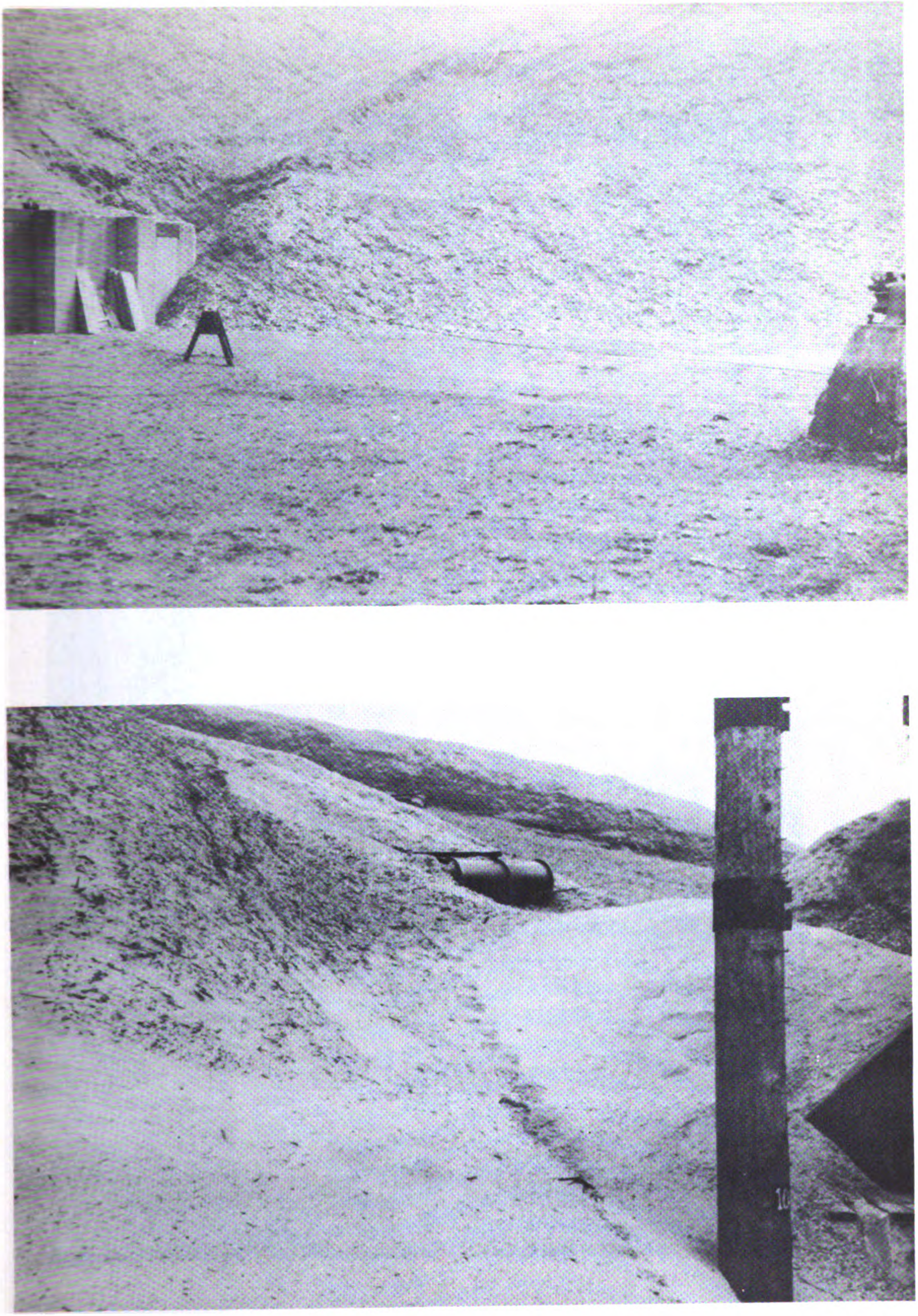

Figure 6. - Drag-line method to move hogged fuel in storage. (Top) Use of large rake. (Bottom) Use of drag bucket.

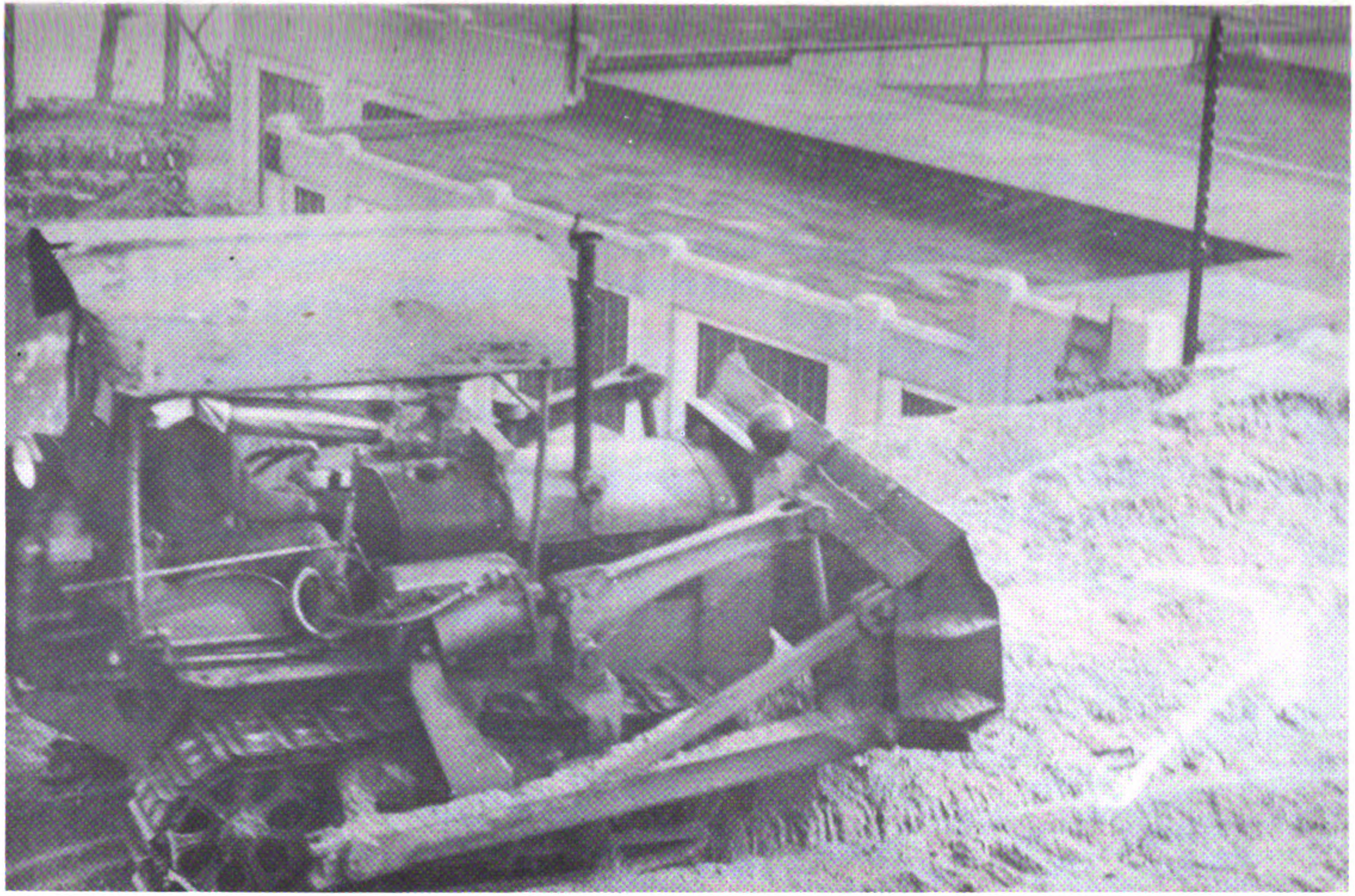

Figure 7. - Bulldozer method of moving hogged fuel in storage.

Spontaneous heating develops in hogged-fuel storage piles. As soon as fresh wood waste is piled, some heating begins from oxidation. In small piles, the heating seldom causes temperatures high enough to produce actual fires; more difficulty from firing occurs when the waste is stored outside than under cover. There is much evidence to show that pieces of metal in contact with the wood waste may create local points of accelerated heating. Hot wood waste is very corrosive to metals, and such contact should be avoided. Boals4/ reports temperature measurements by thermocouples in a pile of hogged fuel 23 feet high, which showed, for a point near the top of the pile, an increase in temperature for about 45 days until a temperature of 190° was reached. The temperature then dropped slightly. However, after about 9 months, the temperature in an outer section of the pile near the base rose rapidly, and smoke odors were noted. An active firing spot then developed, the location being about 2 feet above the ground in a pit formed by the removal of fuel around a pole. Smoke continued to appear at other locations every few days.

The best method of handling a storage fire is to remove the burning or heated fuel at once to the boiler furnace. If necessary, the fire may be controlled by the use of water or steam. Steam usually will not increase the moisture content of the fuel as much as water and can be distributed more readily in all directions over the fuel surfaces.

FURNACE DESIGN

In designing a furnace for wood waste, combustion can be considered from the standpoint of three steps - (1) evaporation of moisture, (2) distillation and burning of volatile matter, and (3) burning of the resultant carbon. The evaporation of moisture and distillation of volatile matter are heat-absorbing processes, the first requiring a relatively great amount of heat, particularly for the high-moisture wood wastes, and the second a small amount. Furnace design must provide that this needed heat for evaporation and distillation be applied effectively, that the volatile matter and fixed carbon be kept hot enough to burn, and that proper air supply for the burning be maintained at the correct places in the furnaces.

Heat for the incoming fuel can be supplied from the burning by reflecting arches and walls and by direct radiation. One means of reducing the moisture content is to pre-dry the wet fuel in dryers heated by hot flue gases leaving the boiler equipment. Mechanical presses that reduce the moisture content of wet wood waste, such as bark from about 80 to 65 percent, are sometimes used. Preheated air for combustion often is used. The positioning of the incoming air for combustion is very important, most installations using an appreciable percentage of "overfire" air. Good turbulence is required to provide a satisfactory mixture of combustible and air; stratification of the gases often causes excessive smoke.

Further factors to be considered in planning equipment for wood-waste burning include the exact type of waste, such as the kind of wood, the percentage of bark, the percentage of sawdust, and the amount of foreign

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4/ Boals, R. B., Experience With Large Woodwaste Piles: Power, vol. 89, May 1945.

material such as sand or other ash-increasing substances. Nonresinous woods, such as redwood and hemlock, burn slower than the resinous woods, such as the pines; the faster-burning woods can contain considerable moisture and yet burn about as readily as the slower-burning woods that contain little moisture. Where there is much sander dust, explosion possibilities must be given consideration and any untimely ignition of dust and air mixtures avoided. Foreign ash in the fuel increases difficulties in operation, lowering boiler capacities by contributing to clinker formation on the grates and slagging on the boiler tubes. It also increases fly ash or cinder carry-over to the stack. Where there is appreciable cinder carry-over, cinder traps often are installed, the cinder being reinjected to the furnace to burn out the remaining combustible.

The Dutch-oven type of furnace extension, shown in figures 8 and 9, is used in many wood-burning installations. This permits evaporation of moisture and distillation of the volatile in a furnace whose temperature is not appreciably affected by the colder boiler surfaces. Refractory walls and arches can be arranged so that the desired temperature can be obtained from the heat supplied by burning some of the volatile and the relatively small amount of resulting or fixed carbon. The high amount of volatile leaving the Dutch oven is burned in the furnace under the boiler.

The flat-grate type of Dutch oven (fig. 8) is ordinarily about 8 feet wide by 9 feet deep and has one feed opening through the top arch. This opening is located so that the depth of the pile at the base of the cone is 8 to 12 inches at the bridge wall and 2 to 3 inches at the front wall. Occasionally, two feed openings are used, one in front of the other, so that two piles are formed. The gases of the front pile pass around and over the rear pile, tending to blanket it. It is generally considered that the use of two such openings tends to reduce capacity. In many installations having the larger boilers, the Dutch oven is more than one "cell" wide, a feed opening being used for each cell, resulting in fuel piles side by side. Often a parting wall of refractory is built between the cells, sometimes just high enough to separate the base of the piles and sometimes reaching to the top arch. The height of the arch over the Dutch oven is quite important from the standpoint of maximum possible boiler loads. The height of the fuel bed is varied by the operator to meet required boiler loads, the height increasing with the load. If the fuel bed is raised too high, however, a choking action results under the arch, which retards combustion. Ordinarily, a distance of about 12 to 15 inches is maintained from the apex of the cone to the top of the arch. A drop-nose arch is often used at the outlet of the Dutch oven. This reflects heat back into the oven and improves mixing of the gases, thus giving better combustion.

The grates in Dutch ovens may be horizontal, set at a slight slope, as in figure 8, or inclined at 35° to 50°, as in figure 9. The percentage of air opening ranges from about 8 to 30. Water-cooling of the grates is practiced a great deal, particularly where the air is preheated. Some grates are cast with water channels to provide direct cooling, and others are cooled

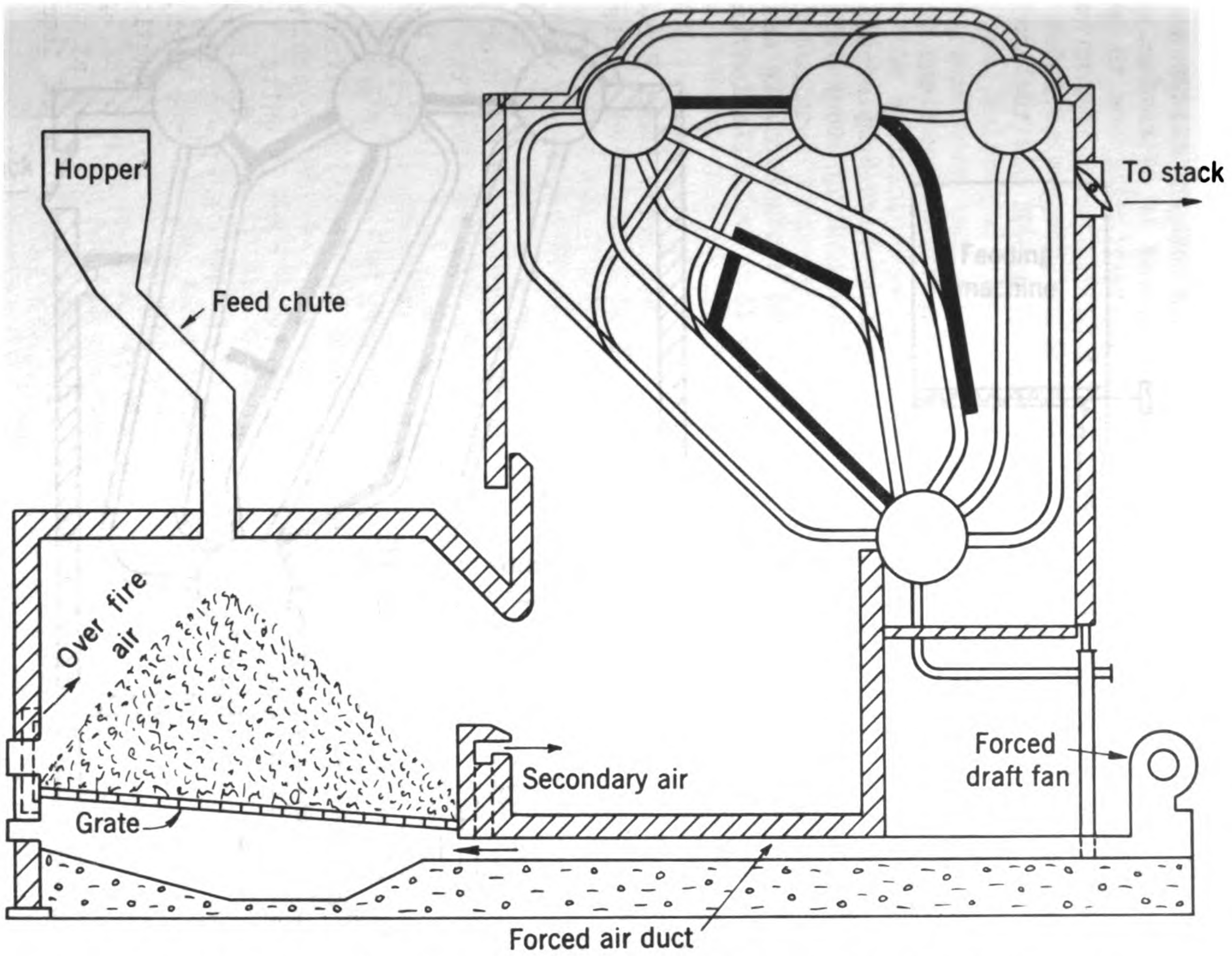

Figure 8. - Dutch-oven type of furnace extension having flat grate set nearly horizontal.

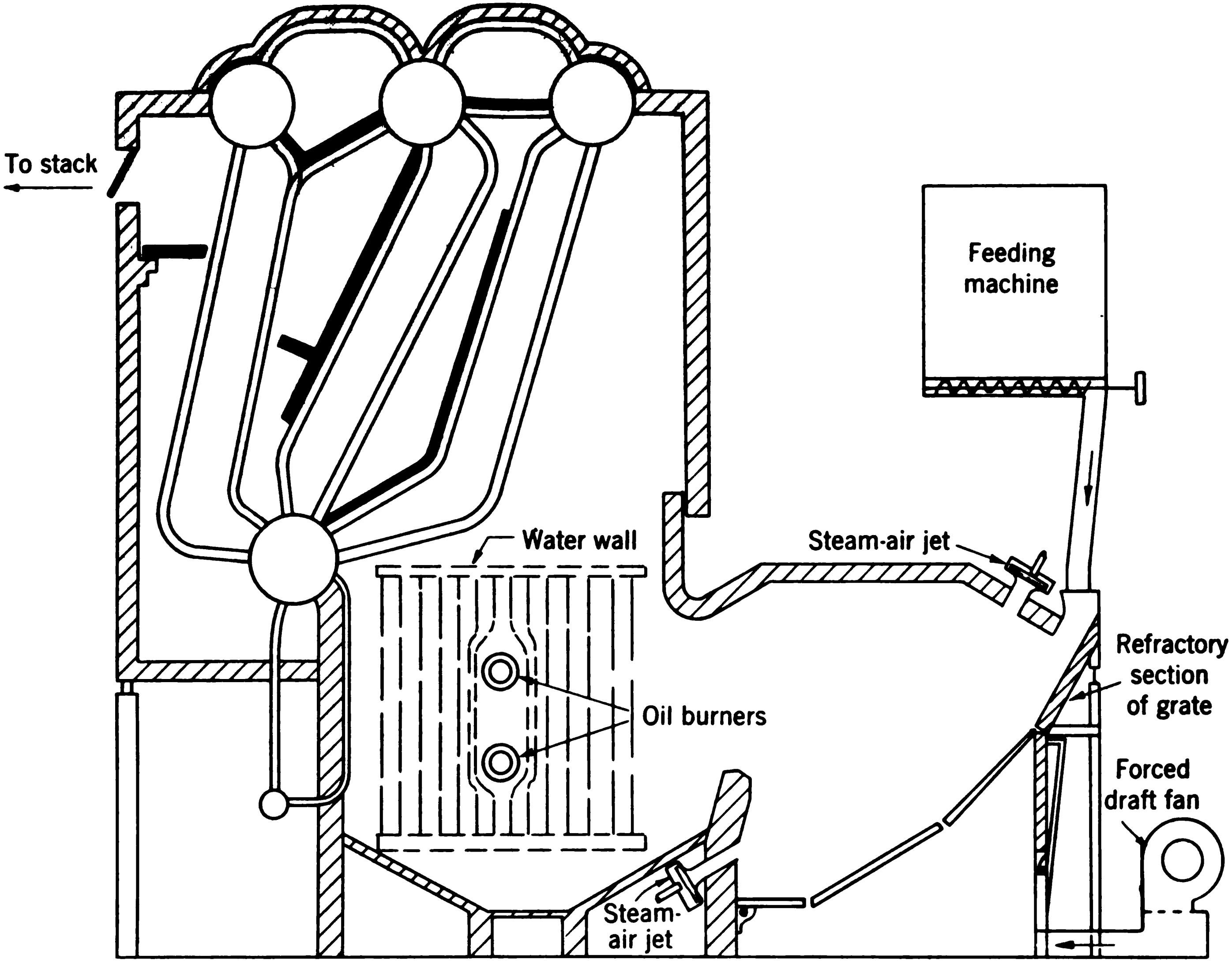

Figure 9. - Dutch-oven type of furnace extension having grate inclined rather steeply.

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by water pipes clamped underside, the grate being cast with an underside curvature, into which standard pipe fits. Tubular-steel water-cooled grates also are used.

With the flat grate, most of the air passing through the grate is directed to the edge of the fuel pile or cone, owing to the greater resistance of its thicker central part. This results in practically all of the combustion on the grate taking place along the rim of the cone. Farther up the pile, combustion is largely on the surface of the cone. This has led to use of over-fire jets in two or more walls of the furnace. Such jets, properly placed, can provide turbulence as well as oxygen, which results in better mixing, more efficient combustion, and less smoke. For forced draft, the maximum air pressure required under a grate with some 20 percent air opening seldom exceeds 0.5 inch of water, many plants using less. The highest pressure needed occurs just before the fire is cleared of accumulated ash, owing to the increased fuel-bed resistance. Cleaning is usually required every 48 to 72 hours; the fuel feed is cut off, the fuel bed lowered, and the ash removed by hand tools.

The inclined grate (fig. 9) requires feeding equipment that will supply a uniform quantity of fuel over the entire width of the grate. The most active burning area is at the bottom of the grate, intensity of burning decreasing gradually to the top, which forms the drying section. The percentage of grate area under active fire decreases as the moisture in the fuel increases. As the fuel at the bottom of the grate is consumed, the fuel bed moves downward, the fresh fuel at the top feeding onto the grate by gravity. This type of grate provides a thinner, more uniformly active fuel bed than the flat types; however, occasionally a portion of the grate area is exposed, owing to a slippage of the bed or to fuel being blown from the grate, and an excessive quantity of air passes through the hole in the fuel bed.

The furnace under the boiler or the final combustion chamber must provide ample space for completing the burning of the combustibles from the Dutch oven. Best results are obtained if full flame length travel is provided, so that the flames do not strike the cold boiler tubes. Secondary air under damper control is often admitted to this combustion chamber; figure 8 shows one method through the bridge wall. Such air tends to give better mixing and shorter flame length. For the larger boilers that carry relatively high loads, water walls often are used (fig. 9). Where dry wood wastes, as from wood-working plants, are to be burned, possible excessively high temperatures may make water walls desirable. Such walls serve as boiler-heating surface and are used to lower the temperature of the furnace a calculated amount, so that less difficulty is experienced with melted ash on the front boiler tubes. Attempt is made to maintain a temperature of the gases, just before they reach the boiler tubes, that is below the melting point of the fly ash, so that it will not slag on the tubes. However, the furnace temperature must not be lowered to the extent that smoke or unsatisfactory combustion results. Water walls also lower furnace refractory maintenance and boiler outage time.

Spreader stokers are now being used for burning hogged fuel (fig. 10). The fuel is screened through about a 2 inch screen, the coarser part not passing the screen being fed to the furnace through a spout at a point considerably above the grate level. Usually the grate is of the traveling type, discharging the refuse continously. Air-preheating is desirable. Such installations give considerable fly ash carry-over, and the use of cinder traps should be considered.

Experiments have been made recently on an underfeed method of firing wood waste that is said to offer desirable features. The wood is moved by a reciprocating ram from a bin through a conveyor pipe to a furnace retort. The fuel is burned in a pile that is supplied with new fuel from underneath. Good control of the fuel feed and also of the air can be obtained to permit of chosen combustion conditions.

Wood waste is often burned with other fuels. Furnace size requirements for wood waste are somewhat similar for oil, gas, or pulverized coal, all of which are used with wood waste. Where there is a relatively small supply of wood, it can be used as an auxiliary fuel itself with many types of fuel-burning equipment, such as hand-fired, stoker-fired, or pulverized coal, oil, or gas. Such wood waste is usually directed to the combustion chamber through an auxiliary chute.

Sawdust with the chips removed is frequently used as the fuel for heating commercial buildings and also residences in areas adjacent to the source of large quantities of this product. A small furnace of the Dutch-oven type is connected to the ordinary furnace at the opening provided for the removal of ashes when firing coal (fig. 11). The grate is removed, and the ash pit of the conventional furnace is lined with refractory and becomes part of the combustion chamber. The Dutch oven is equipped with either a step grate or inclined-feed grate that slopes to a flat perforated plate, the sawdust being fed from a hopper. Primary air for combustion is supplied through an adjustable opening that directs the air under the fuel bed. Secondary air is admitted through an opening over the fuel bed, usually in the top of the Dutch oven, and equipped with a cover, so that the area of opening can be adjusted to the load conditions. The rate of combustion can be regulated either by manual operation or automatic thermostatic control of the draft openings. The fire is usually cleaned every 24 to 72 hours, depending on load conditions.

Table 2 lists general data on a number of wood-burning installations that are examples of present day plants.

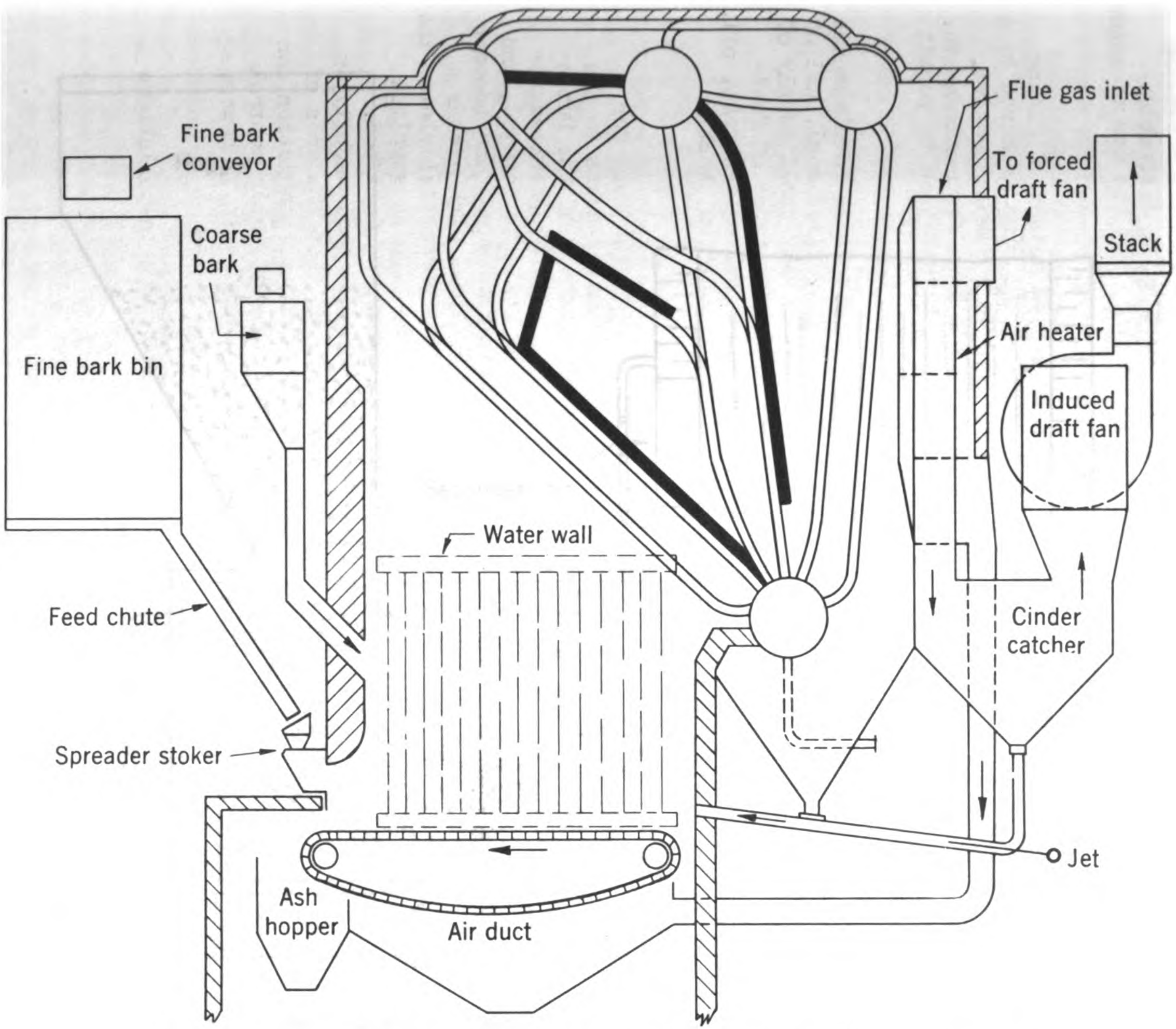

Figure 10. - Application of spreader stoker for burning wood waste.

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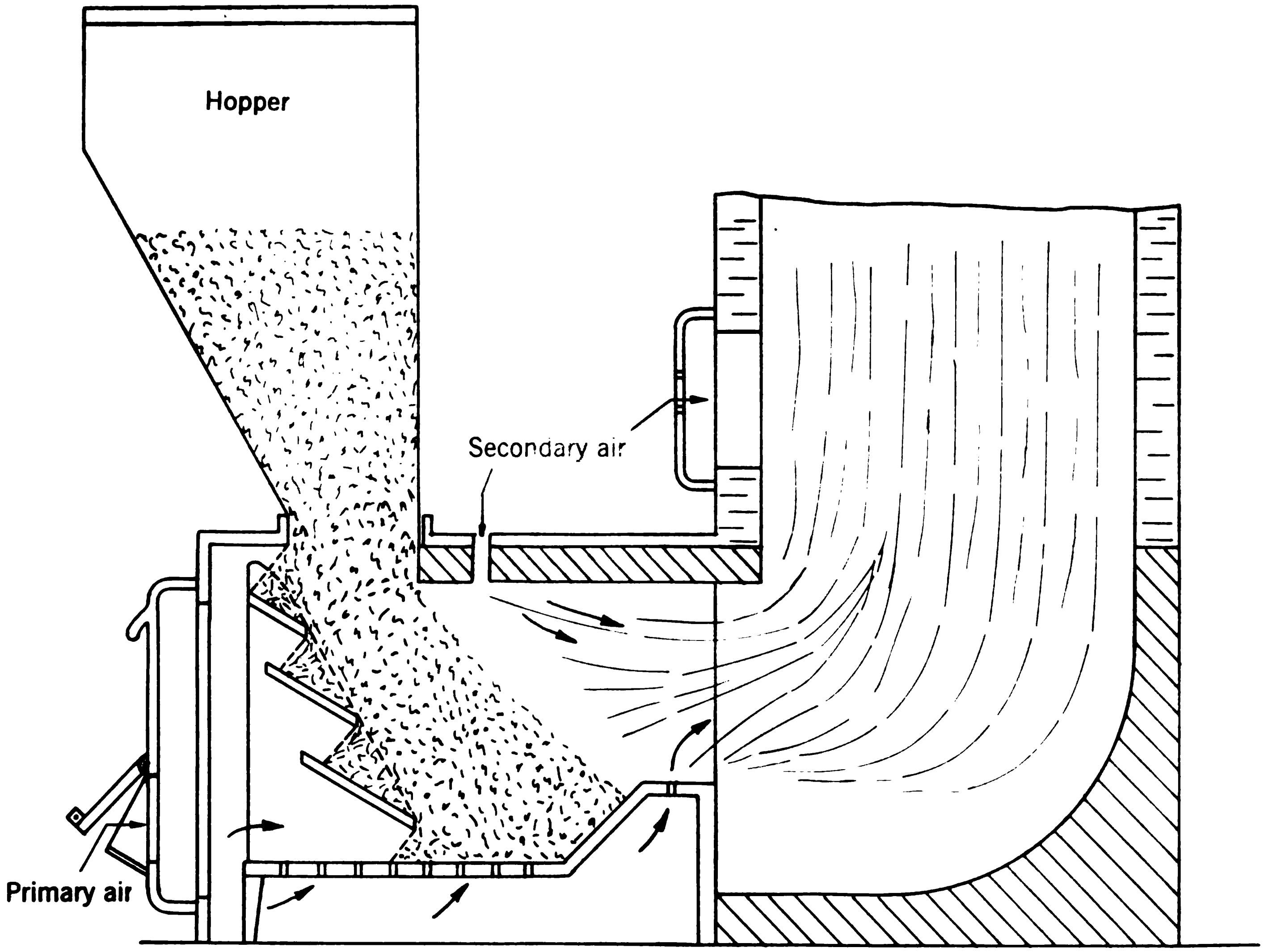

Figure 11. - Application of Dutch-oven extension to ordinary small heater.

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